UPGRADED BOTTLED BIOGAS
A GREEN AND LOW-COST FUEL FOR AUTOMOBILES IN INDIA

Upgrading and bottling of biogas, a renewable energy source, can help in both waste management and building a sustainable environment. **Virendra Kumar Vijay** writes about on-going research developments in the field.

Enhanced energy security and climate change mitigation are the main drivers for the transformation of the energy system from one based on fossil fuels to that on renewable sources. Biomass has to play a key role in this transformation to a low-carbon economy. Worldwide, biomass accounts for more than two-thirds of all renewable energy supplies. Among biomass sources, biogas is an interesting option with a large potential, offering many exciting possibilities to supplement existing fuels and thereby reducing our dependence on fossil fuels.

WHAT IS BIOGAS?

For the uninitiated, biogas is formed by the digestion of organic waste including manure, sewage sludge, municipal solid waste, biodegradable waste, and seedcake into usage energy in a digester or in a landfill site. Biogas composition and its contaminants are dependent on the type of feedstock used. Biogas production is basically an anaerobic digestion which is considered to be a sustainable bio-conversion technology as it produces biogas which is a renewable gaseous fuel; it also stabilizes and reduces the volume of waste.

Rapid industrialization and population increase has resulted in the generation of huge quantities of waste, both solid and liquid, in industrial sectors such as sugar, pulp and paper, food processing, sugar/starch, distilleries, dairies, tanneries, slaughterhouses, poultry farms, etc. Hence, there is a huge potential for the installation of medium (85–1,000 m^3/d) to large-size (>1,000 m^3/d) biogas plants in the country depending upon the availability of the feedstock.

Biogas typically consists of methane (50–70%), carbon dioxide (30–45%), traces of water vapour, and hydrogen sulfide (H_2S). The composition varies according to the feed material used. Biogas has a heating value of 20–24 MJ. The presence of methane renders it combustible while carbon dioxide, besides being non-combustible, restrains

Anaerobic Digestors (overhead view)

its compressibility thereby making it difficult to be stored in containers. Raw biogas has to be upgraded to natural gas quality in order to be used in vehicles that are designed to use natural gas. This means that carbon dioxide (CO_2), hydrogen sulphide (H_2S), ammonia, particles, and water — and sometimes other trace compounds — have to be removed so that it can be used in vehicles. This is because by itself, biogas has a methane content of more than 90 per cent by volume. This upgraded gas is generally referred to as Biomethane which is bottled at discharge pressure of 200 bar. This is termed as Compressed Biogas (CBG). Further, using a CNG dispensing cable and a nozzle to NZS standards, this CBG can be used for filling the gas into the vehicles. The new biogas standard BIS:16087(2013) has been developed by the Bureau of Indian Standards (BIS)for its utilization in vehicles (Table I).

FEEDSTOCK OF BIOGAS AND ITS PRODUCTION

There are around 300 distilleries throughout India which collectively have a potential of producing 1,200 million Nm^3 biogas along with and 2,000 tannery units capable of producing 787,500 Nm^3 of biogas. The increasing number of poultry farms can also add to biogas productivity, as with the current population of 649 million birds, another 2,173 million Nm^3 of biogas can be generated.

As per the *Report of Planning Commission on Development of Biofuels* published by the Government of India in 2013, an estimated area of 13.4 million hectares of marginal/wastelands that are suited to growing Jatropha and this can cater to large-scale plantings so as to meet the blending targets fixed by the Government of India. Non-edible seed cake produced after the extraction of biodiesel has higher potential to produce biogas as slurries of the dung have high water content (in excess of 90%) which leads to relatively low specific methanogenic capacities. Table 2 shows biogas production for different feedstock.

BOTTLING OF BIOGAS

Upgraded and bottled biogas is a renewable energy source which can help both in waste management and in building a clean and sustainable environment. This technology is an economically viable option for biogas produced at medium to large scales. The Ministry of New and Renewable Energy (MNRE) has developed a national master plan for waste-to-energy projects along with the National Biogas and Manure Management Programme and biogas fertilizer plants for biogas upgradation and bottling programme with assistance from UNDP/GEF. The Government of India is exploring anaerobic digestion potential from all sources — municipal solid waste, crop residue, sewage sludge, animal manure, industrial waste which includes distilleries, dairy plants, pulp and paper, poultry, slaughter houses, sugar industries excluding waste water treatment plant — for two significant reasons; one being rocketing fuel pricing and the other stringent environmental regulations. The total potential of biogas from all sources has been estimated to be 48,382 million m^3/year. This amount when upgraded — and when assumed that 50 per cent of total upgraded biogas contributes towards transport sector and 50 per cent for cooking sector — then according to the *Indian Petroleum and Natural Gas Statistics 2011–2012*, this much upgraded and bottled biogas can fulfill 43.4 per cent of total transport sector demand and similarly around 41.7 per cent of cooking sector needs.

A biogas bottling system (see Figure 4) typically consists of the following equipment:

- High pressure gas compression
- Storage for upgraded biogas
- Dispensing nozzle system

TABLE 1: BIS Standards for Biogas Composition in India (16087:2013 Biogas Specification)

Sl. No.	Biogas Components	Percentage
1	CH_4, %, Min	90
2	Moisture, mg/m^3, Max	16
3	H_2S, mg/m^3, Max	30.63
4	$CO_2+N_2+O_2$, % Max (v/v)	10
5	CO_2, %, Max (v/v (when intended for filling in cylinders)	4
6	O_2, %, Max (v/v)	0.5

Source: Bureau of Indian Standards

TABLE 2: Biogas Production According to Feedstock

Feedstock	Gas Yield (m^3/kg)	Methane (%)
Cattle dung	0.297	55
Pig	0.40	65
Poultry	0.45	70
Straw	0.341	51
Grass silage	0.576	52
Municipal solid waste	0.308	60
Jathropa curcas seedcake	0.640	66.5
Pongamia pinnata seedcake	0.738	62.5

Source: National Society for Clean Air for Environmental Protection (2006), *Biogas as a Road Transport Fuel: An Assessment of the Potential Role of Biogas as a Renewable Transport Fuel*; M Pöschl, S Ward, P Owende (2010), 'Evaluation of Energy Efficiency of Various Biogas Production and Utilization Pathways', *Appl Energy* 87: 3305–21.; AsamZaki-ul-Zaman, T G Poulsen, A Nizami, R Rafique, G Kiely, and J D Murphy, 'How Can We Improve Biomethane Production per Unit of Feedstock in Biogas Plants?' *Appl Energy* 88: 2013–18.

> THE TRAILER MOUNTED MOBILE BIOGAS UPGRADING AND BOTTLING UNIT CAN BE TAKEN UP BY ENTREPRENEURS IN RURAL AREAS WHO SELL CBG LOCALLY FOR TRACTORS AND TRANSPORT VEHICLES IN THESE AREAS.

INDIAN INSTITUTE OF TECHNOLOGY

Indian Institute of Technology, Delhi (IIT-D), has developed a small-scale biogas upgrading system using water scrubbing technology (20 m^3/h system). The water-scrubbing-based biogas upgradation and compression/ bottling system is patented IIT-D for enhancing the utility of biogas application that is, in vehicles and cooking applications. The system consists of a water scrubbing column and a methane-enriched biogas compression system. The commercial viability of biogas purification and bottling

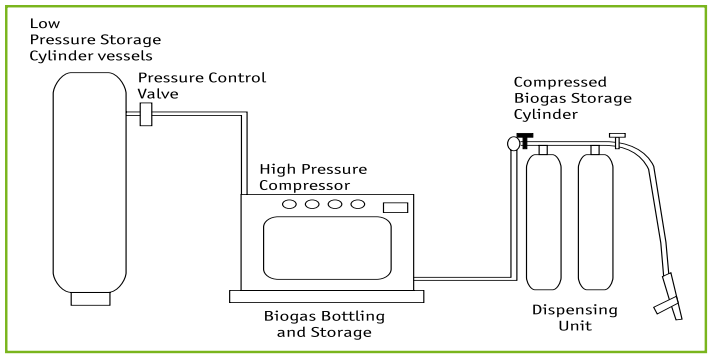

Figure 4: Biogas Bottling System

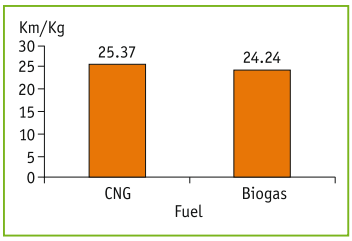

Figure 1: Fuel Consumption

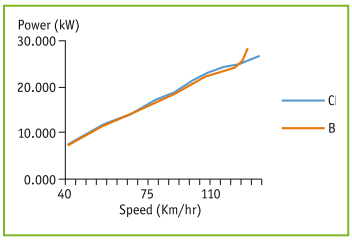

Figure 2: Power Curve

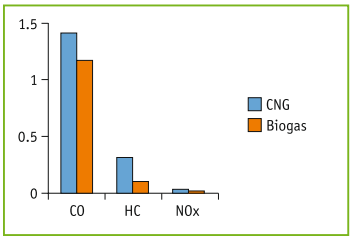

Figure 3: Emissions Chart

UTILIZATION OF BIOGAS FOR TRANSPORTATION

As per NGVA statistics in 2007:

- 12,000 vehicles were being fuelled with upgraded biogas worldwide, increasing to 70,000 biogas-fuelled vehicles by 2010
- In Europe, Sweden reports that more than half of the gas used in its 40,029 natural gas vehicles is biogas
- Germany and Austria have established targets of 20% biogas in natural gas vehicle fuel
- In the United States, biogas vehicle activities have been on a smaller scale

As shown in Table 3, the majority of natural gas vehicles are in the developing countries but in all of these countries NGVs are being run on natural gas due to the availability of the natural gas grid in most areas. In these countries, biogas production, upgrading and bottling is at an early stage and small scale, hence grid injection or bottling of upgraded biogas is non-existent.

However, few are aware that IIT Delhi has successfully launched India's first biogas-fuelled passenger car. Compressed biogas was tested on a regular CNG car for over 15,000 km. Good news is that environment emissions were seen to be lower than that in CNG. Also, existing CNG vehicles need not undergo any modification to be compatible to CBG.

BENEFITS

- Anaerobic digestion reduces the emission of green house gases into the atmosphere.
- It is a carbon neutral fuel.
- Dung management and sanitary toilets, attached to biogas digesters lead to better hygienic conditions
- The by-product of biogas technology, i.e., bio slurry is an excellent organic fertilizer which can be applied to farmers gardens
- Flexibility of feed stocks
- Closed system design for odour control
- It has lower emission levels than natural gas and diesel

ICAT TEST RESULTS OF CAR ENGINE

FOR FUEL CONSUMPTIONS AND POWER GENERATION, THE ENGINE GIVES SIMILAR RESULTS FOR BIOGAS AND CNG, WHILE IN CASE OF EMISSION BIOGAS GIVES LESS EMISSION THAN CNG.

Biogas three-wheeler vehicle

plant can be attained above 500m^3/d capacity. Waste required for above capacity is around 20 tonne/d of cattle dung or 10 tonne/d of pig, poultry or food waste. This plant produces approximately 200 kg/d Compressed Biogas (CBG) and 3 tonne/d of semi-dried manure. Its payback period ranges from one year to four years depending upon the capacity of the plant, cost of raw material for gas production, and selling price of CBG. The system includes an anaerobic digester, biogas purification plant, high pressure compressor, and a cylinder storage cascade. Initial cost of the complete plant is approximately Rs 25 million excluding the cost of land for 1,000m^3/d. CBG can be used as a replacement of commercial LPG or vehicular fuel with typical selling cost of Rs 70/Kg. General selling price of manure is Rs 3–4/kg. At IIT-Delhi, regular CNG car has been tested on CBG for more than 15,000km. It was noted that existing CNG vehicles need not undergo any modifications to be compatible to CBG as a fuel. The fuel economy and mass emission of the vehicle fuelled with the Compressed Biogas (CBG) with 93 per cent CH_4 and CNG were evaluated. The emissions such as CO, HC, and NO_x are found to be marginally higher with the CNG than CBG with emission norms meet to the BS IV Norms. There is no significant change in millage of the vehicle fuelled with the CBG (24.11 km/kg) as compared to CNG (24.38 km/kg).

The Biogas Development and Training Centre, IIT-Delhi, is working to develop a mobile unit for biogas enrichment based on water scrubbing and pressurized swing adsorption system. This idea is for utilizing the left over biogas in small-sized biogas plants (<85 m^3/d) installed in villages for collection, upgradation, and bottling. The trailer mounted mobile biogas upgrading and bottling unit can be taken up by entrepreneurs in rural areas who sell CBG locally for tractors and transport vehicles in rural areas. In future, this mobile technology will generate entrepreneur and employment opportunities for the youth of rural India.

CONCLUDING THOUGHTS

Biogas is a potential renewable energy and carbon neutral source for rural as well as for urban India. There is a need for tax incentives, support, and regulations in this direction from the government to enable our country to be self-reliant in the energy sector. Taking biogas generation as a base activity and compressing it for decentralized power production, cooking needs at highway motels, industrial complex, dairy, food processing units can be taken up, which will not only help us towards reducing unemployment and alleviating economy, it will also help us mitigate climate change by the use of bio-energy in an efficient way. AU

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A biogas vehicle


Equipment at IIT-Delhi

TABLE 3: Global Scenario

Country	No. of Natural gas Vehicles	% all ngvs in world	Biomethane share in NGV market (%)
Iceland	255	0.00	100
Norway	762	0.01	10.0
Sweden	40,029	0.28	59.1
Switzerland	10,228	0.07	21
Germany	96,215	0.66	6
France	13,500	0.09	3
Finland	985	0.01	3

Source: Worldwide NGV Statistics, 2012